Coastal Water Quality Monitoring Manual

Parameters and Techniques

Department of Planning and Natural Resources
Division of Coastal Zone Management

September 2001

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Department of Planning and Natural Resources
Division of Coastal Zone Management

Dean C. Plaskett, Esq., Commissioner
Janice D. Hodge, Director

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ACRONYMS

BMP - Best Management Practice
CZM - Coastal Zone Management
DPNR - Department of Planning and Natural Resources
DPNR-CZM- Department of Planning and Natural Resources, Division of Coastal Zone Management

DO - Dissolved Oxygen
GPS - Global Positioning System
NTU - Nephelometric Turbidity Unit
PSU - Practical Salinity Unit

U.S.V.I.- United States Virgin Islands

FOREWORD

This manual was developed as an easy-to-use guide for the staff of the Department of Planning and Natural Resources, Division of Coastal Zone Management (DPNR-CZM), Government of the United States Virgin Islands. This manual is meant to standardize the water quality monitoring program of the Division of Coastal Zone Management (CZM). As such, it does not present the wide range of techniques usually expected in a comprehensive monitoring program. Instead, it has been developed to meet the specific need for monitoring marine water quality impacts resulting from construction activities, particularly impacts related to sediments in stormwater runoff. The parameters to be used in the monitoring program were selected with this specific need in mind, and the sampling equipment recommended was determined to a large extent by the circumstances and mobility requirements of the Division of Coastal Zone Management.

More specifically, this monitoring program is part of the process of evaluating the efficacy of the mitigation measures and best management practices utilized within the development control process of the CZM program. As the program evolves, the techniques described herein should be supplemented or replaced by more rigorous monitoring and evaluation tools.

While the CZM water quality monitoring program has a specific focus, the data it generates is meant to be supplemented by, and analyzed within the context of, the more extensive ambient water quality monitoring program of the DPNR.

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The project team, which functioned under the general guidance of Dr. Henry Smith, was composed of Dr. Marci Bortman, Dr. Richard Nemeth, and Mr. Lloyd Gardner. Mr. Stevie Henry of the Conservation Data Center, University of the Virgin Islands, prepared the maps and other graphical representations.

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I. INTRODUCTION

PURPOSE

Pursuant to Title 12, Chapter 21, Section 903(b), the coastal zone management program of the Department of Planning and Natural Resources (DPNR) was established to:

1. Protect, maintain, preserve, and where feasible, enhance and restore the overall quality of the environment in the coastal zone, the natural and man-made resources of the coastal zone for the benefits of residents and visitors of the Virgin Islands.

2. Promote economic development and growth in the coastal zone and consider the need for the development of greater than territorial concern by managing: (a) the impacts of human activity, and (b) the use and development of renewable and non-renewable resources as to maintain and enhance the long-term productivity of the coastal environment.

3. Assure priority for coastal-dependent development over other development in the coastal zone by reserving areas suitable for commercial uses, including hotels and related facilities, industrial uses, including port and marine facilities, and recreational uses.

4. Assure the orderly, balanced utilization and conservation of the resources of the coastal zone, taking into account the social and economic needs of the residents of the Virgin Islands.

5. Preserve, protect, and maintain the trustlands and other submerged and filled lands of the Virgin Islands so as to promote the general welfare of the people of the Virgin Islands.

6. Preserve what has been a tradition and protect what has become a right of the public by insuring that the public, individually and collectively, has and shall continue to have the right to use and enjoy the shorelines, and to maximize public access to and along the shorelines consistent with the protected rights of private property owners.

7. Promote and provide affordable and diverse public recreational opportunities in the coastal zone for all residents of the Virgin Islands through acquisition, development, and restoration of areas consistent with sound resource conservation principles.

8. Conserve ecologically significant resource areas for their contribution to marine productivity and valuable wildlife habitats, and preserve the function and integrity of reefs, marine meadows, salt ponds, mangroves, and other significant natural areas.

9. Maintain or increase coastal water quality through control of erosion, sedimentation run-off, siltation, and sewage discharge.

10. Consolidate the existing regulatory controls applicable to uses of land and water in the coastal zone into a single unified process consistent with these provisions, and coordinate therewith the various regulatory requirements of the United States Government.

11. Promote public participation affecting coastal planning and development.

Within this broad mandate, the Coastal Zone Management Act requires that development activity taking place in Tier 1 of the coastal zone first obtain a permit from the Department of Planing and Natural Resources, Division of Coastal Zone Management (DPNR-CZM). The goal of the permitting process is to ensure that the negative impacts of coastal development on the coastal environment are prevented, or at least, kept within acceptable limits. Thus, coastal zone permits generally stipulate measures (impact mitigation measures and best management practices) that must be undertaken during the development activity to ensure environmental protection.

The water quality monitoring program of the Division of Coastal Zone Management (CZM) is designed to achieve the following objectives:

1. To detect changes in coastal water quality associated with development activity; and

2. To determine the effectiveness of mitigation measures in coastal zone permits, and ultimately the effectiveness of best management practices developed in the CZM program.

DESIGN CONSIDERATIONS

The selection of parameters to be measured, the monitoring equipment, and basic methodologies to be used are determined by a number of factors, namely:

i. The major concern for water quality impact from the construction phase of development activity is soil erosion and sedimentation in surface run-off.

ii. The monitoring activity must be able to generate results very quickly, in the event environmental baseline conditions are exceeded, and remedial action has to be taken.

iii. The absence of laboratory facilities forces DPNR to rely on portable equipment, thus enabling the most flexibility in program implementation.

The random nature of development projects dictates that the environmental baseline conditions set for each project will be limited. Thus, in setting the sample stations, care must be taken to ensure that at least one station coincides with one of the permanent monitoring stations (Appendix 1) established by DPNR's Division of Environmental Protection. This assumes that a permanent monitoring station is located in the area in question. The link to permanent monitoring stations allows the analysis of the sampling results to be based on a much larger database. This in turn allows the CZM staff to determine whether changes in water quality are "normal" or statistically significant, especially if such changes exceed the applicable water quality standards.

II. COASTAL WATERS OF THE US VIRGIN ISLANDS

CLASSIFICATION AND STANDARDS

The Water Quality Standards for Coastal Waters of the Virgin Islands are contained within the “Rules and Regulations Relative to Water Quality Standards for Coastal Waters of the Virgin Islands. Revised July 20, 1973. Approved July 26, 1973, File No. 750”.

General Water Quality Criteria

The Regulations state that “all surface waters shall meet generally accepted aesthetic qualifications and shall be capable of supporting diversified aquatic life. These waters shall be free of substances attributable to municipal, industrial, or other discharges or wastes as follows:

(a) Materials that will settle to form objectionable deposits.
(b) Floating debris, oil, scum, and other matter.
(c) Substances producing objectionable color, odor, taste or turbidity.
(d) Materials, including radionuclides, in concentrations or combinations which are toxic or which produce undesirable physiological responses in human, fish and other animal life, and plants.
(e) Substances and conditions or combinations thereof in concentrations which produce undesirable aquatic life”.

Class A Waters

(a) Best Usage of Waters: Preservation of natural phenomena requiring special conditions, such as the Natural Barrier Reef at Buck Island, St. Croix and the Under Water Trail at Trunk Bay, St. John.

(b) Quality Criteria: Existing natural conditions shall not be changed.

(c) Legal Limits:

i. Within 0.5 miles of the boundaries of Buck Island’s Natural Barrier Reef, St. Croix.

ii. Trunk Bay, St. John.

Class B Waters

(a) **Best Usage of Waters:** For propagation of desirable species of marine life and for primary contact recreation (swimming, water skiing, etc.).

(b) **Quality Criteria:**

i. **Dissolved Oxygen**: Not less than 5.5 mg/l from other than natural conditions.

ii. **pH**: Normal range of pH must not be extended at any location by more than ± 0.1 pH unit. At no time shall the pH be less than 7.0 or greater than 8.3.

iii. **Temperature**: Not to exceed 90°F at any time, nor as a result of waste discharge to be greater than 1.5°F above natural. Thermal policies also apply.

iv. **Bacteria**: Shall not exceed a geometric (log) mean of 70 fecal coliforms per 100 ml. by MF or MPN count.

v. **Dissolved Gas**: Total dissolved gas pressures shall not exceed 110 percent of existing atmospheric pressure.

vi. **Phosphorus**: Phosphorus as total P shall not exceed 50 ug/l in any coastal waters.

vii. **Suspended, colloidal, or settleable solids**: None from waste water sources which will cause disposition or be deleterious for the designated uses.

viii. **Oil and floating substances**: No residue attributable to waste water nor visible oil film nor globules of grease.

ix. **Radioactivity**:

- **Gross beta**: 1000 picocuries per liter, in the absence of Sr 90 and alpha emitters.
- **Radium-226**: 3 picocuries per liter.
- **Strontium-90**: 10 picocuries per liter.

x. **Taste and odor producing substances**: None in amounts that will interfere with the use for primary contact recreation, potable water supply or will render any undesirable taste of odor to edible aquatic life.

xi. **Color and turbidity**:

- A Secchi disc shall be visible at a minimum distance of 1 meter.

- A maximum nephelometric turbidity unit reading of three (3) shall be permissible.

(c) Legal Limits:

i. All other coastal waters not classified Class “A” or Class “C”.

Class C Waters

(a) Best Usage of Waters: For the propagation of desirable species of marine life and primary contact recreation (swimming, water skiing, etc.).

(b) Quality Criteria:

i. **Dissolved oxygen**: Not less than 5.0 mg/l from other than natural conditions.

ii. **pH**: Normal range of pH must not be extended at any location by more than ± 0.1 pH unit. At no time shall the pH be less than 6.7 or greater than 8.5.

iii. **Bacteria**: Shall not exceed a geometric (log) mean of 200 fecal coliforms per 100 ml. by MF or MPN count.

iv. **Taste and other odor producing substances**: None in amounts that will interfere with the use for potable water supply or will render any undesirable taste or odor to edible aquatic life.

v. **Color and turbidity**: A Secchi disc shall be visible at a minimum depth of one (1) meter.

vi. Other provisions for Class B waters shall apply.

(c) Legal Limits:

i. St. Thomas:
   - St. Thomas Harbor, beginning at Rupert Rock and extending to Haulover Cut.
   - Crown Bay, enclosed by a line from Hassel Island at Haulover Cut to Regis Point at West Gregeri Channel.
   - Krum Bay.

ii. St. Croix:
   - Christiansted Harbor, from Fort Louise Augusta to Golden Rock.

- Frederiksted Harbor, from La Grange to Fisher Street
- Hess Oil Virgin Islands Harbor.
- Martin-Marietta Alumina Harbor.

Table 1: U.S. Virgin Islands Coastal Water Quality Standards

Parameter	USVI Territorial Standards		
	Class A Waters	Class B Waters	Class C Waters
Secchi Disk Depth (m)	*	1	1
Turbidity(ntu)	*	3	3
pH	*	7.0-8.3	6.7-8.5
Temperature (°F)	*	≤ 90° F**	≤ 90° F**
Dissolved Oxygen (mg/l)	*	≥5.5 mg/l	≥ 5.0 mg/l

Oil and Floating Substances	*	No residue from waste water, no visible oil film nor globules of grease	No residue from waste water, no visible oil film nor globules of grease
Taste and Odor Producing Substances	*	None in amounts that will interfere with primary contact recreation, potable water supply, edible aquatic life	None in amounts that will interfere with potable water supply or edible aquatic life
* Existing conditions shall not be changed ** Temperature changes from waste discharge shall not exceed 1.5° F.			

WATER CLASS MAPS

The maps depicting the location of Classes A, B, and C waters of the U.S. Virgin Islands (U.S.V.I.) was produced based on interpretation of the Rules and Regulations Relative to Water Quality Standards for Coastal Waters of the Virgin Islands. Revised July 20, 1973. Approved July 26, 1973, File No. 750. This regulation states the legal limits (boundaries) of the different water classes in the U.S.V.I.

However, the interpretation highlighted a number of discrepancies in the description of the legal limits. Additionally, it identified language in the regulations that could support multiple interpretations. These discrepancies, assumptions, and interpretations, as well as the solutions used to produce the enclosed maps, are given in this section.

(a) Limit of Water Quality Class Boundaries

The regulations do not provide a definition of coastal waters for the U.S.V.I. As such, for the purposes of this monitoring program, the limit of the water quality classes is taken to be the territorial limit, this being three (3) miles around the three main islands, St. Croix, St. John, and St. Thomas.

(b) Class A Water Limits – Buck Island

The legal limits identify the barrier reef system around Buck Island, not the island itself. It is assumed that the boundary of the Buck Island National Monument encloses the barrier reef. The boundary of the Class A waters around Buck Island is therefore interpreted to mean 0.5 miles from the (pre-2000) boundary of the Buck Island National Monument.

(c) Class C Water Limits - Fredericksted

Though the legal limits specify Fredericksted Harbor, Fredericksted does not have a harbor, and the seaward (western) limit of the Class C waters in this area was therefore not properly defined. This boundary was determined by extending the northern and southern boundaries westward to approximately the length of the cruise ship pier.

(d) Class C Water Limits – St. Thomas Harbor

The boundary for this area is supposed to start at Rupert Rock, and extend to Haulover Cut. This creates a number of problems. First, Rupert Rock is located in the harbor just south of the dock at Havensight Point, and is unconnected to St. Thomas proper. The boundary in this area was completed by extending the line from Rupert Rock east to the closest point at the base of Lisenlund Hill. Second, Haulover Cut is the passage between St. Thomas and Hassel Island. As such, the line from Rupert Rock cannot be extended to Haulover Cut, which is on the western side of Hassel Island. In trying to translate this information to map form, the line from Rupert Rock was extended to the northernmost point of Hassel Island.

These attempts at clarification and clear demarcation of the classes of water resulted in the maps as shown.

Other Considerations

The standards specified for the water classes were approved in 1973. The water quality at a number of sites may have since changed. For example, based on the use of the area as docks and for anchorage, it can be safely assumed that the water quality at Cruz Bay (St. John) and the environs of the Redhook ferry dock (St. Thomas) has deteriorated, and may presently be Class C standard. The environs of a number of the marinas may also be experiencing similar conditions.

The implication is that a small number of sample events prior to construction activity may not generate a true picture of the background (baseline) conditions of a site. This underscores the need to ensure correlation between the CZM monitoring program and the more comprehensive monitoring program of the Division of Environmental Protection.

EXISTING WATER QUALITY MONITORING PROGRAM

The existing water quality monitoring program of the DPNR is conducted by the Division of Environmental Protection, and is focused on the monitoring of ambient water quality. The sampling program covers 140 stations, of which 64 are on St. Croix, 19 are on St. John, and 57 are on St. Thomas (Appendix 1). Sampling is done on a monthly basis, and involves the following parameters:

- Temperature;
- Dissolved Oxygen;
- Turbidity;
- Secchi Depth;
- Salinity; and
- Fecal Coliform Bacteria.

Except for fecal coliform and turbidity, measurement of the different parameters is conducted in the field using the appropriate instruments. In the case of fecal coliform, the samples are usually sent to a private laboratory on St. Croix for analysis.

Sampling stations on St. Croix have been located using a global positioning system (GPS). Other than that, there are no written sampling protocols or standard operating procedures for the ambient water quality monitoring program. Quality control is carried out by the quality assurance office of DPNR on St. Croix, which uses the quality assurance/quality control guidelines developed by the U.S. Environmental Protection Agency.

III. WATER QUALITY PARAMETERS

INTRODUCTION

Coastal waters should be monitored before, during, and after construction activities in the coastal zone and marine environment to ensure that there is no adverse impact associated with the development. One major source of pollutants to marine waters from development activities is stormwater runoff. The primary pollutant carried by stormwater runoff is sediment (Schueler 1987). Sediment in runoff can cloud the water, impeding primary production by phytoplankton and submerged aquatic vegetation, and it can impair coral reef habitats. Although effects from toxic chemicals, bacteria, biological oxygen demand, oil and grease, trace metals, chlorides, and nutrients can also be a threat to coastal waters, turbidity from sediment inputs is the most common and persistent source of marine pollution from construction activities.

For the purposes of this monitoring program, the Department of Planning and Natural Resources, Division of Coastal Zone Management (DPNR-CZM) decided to focus only on measuring potential pollutants *in situ* (in the field), which may have been generated from runoff from construction sites. As such, the wide range of parameters usually covered as part of more comprehensive monitoring programs will not be included here. Given the focus of the program, parameters of importance include:

- Water clarity;
- Temperature;
- Salinity;
- Dissolved oxygen; and
- pH.

These parameters will be discussed in this chapter. Chapter 4 deals with monitoring noticeable (qualitative) changes in the marine environment, such as the presence of oil and gas, odors, floatable debris, or fish kills.

Although this manual focuses on development activities in close proximity to the coastal waters, it is important to note that pollutants in stormwater from further inland can make their way to coastal waters. Factors such as runoff velocity, size and weight of soil particles, drainage channel roughness, and flow obstructions will determine whether sediment and other pollutants in runoff will be carried to coastal waters from inland areas. As water runoff slows down, sediment settles out and becomes deposited. Therefore, best management practices (BMPs) for inland construction should also incorporate ways to not only retain stormwater runoff on-site, but also to reduce the rate of discharge of stormwater.

DESCRIPTION OF PARAMETERS

Water Clarity

An important characteristic of tropical and subtropical waters is their high water clarity. Water clarity is evaluated by measuring the transparency or turbidity of water. Particles typically causing turbidity consist of clay, silt and other fine-grained particles, organic matter, plankton, and other microscopic organisms (American Public Health Association 1989).

Water transparency is an extremely important factor in ecosystem functioning in tropical and subtropical waters. Corals and seagrasses depend on sufficient penetration of light through water to flourish. Large inputs of sediment or prolonged exposure to high levels of turbidity from suspended particles in the water can reduce light availability, leading to decreased abundance and reduced growth of coral species (Tomascik and Sander 1985; Hawker and Connell 1992). Sedimentation may also lead to abrasion and energy diversion from metabolic functions to sediment rejection. In extreme cases, sedimentation may smother corals.

Instruments commonly used to measure water clarity include:

- Secchi Disk;
- Nephelometer/Turbidimeter;
- Light Meter;
- Transmissiometer;
- Radiometer; and
- Spectrophotometer.

Secchi Disk

One of the most common measures of water column transparency is secchi disk depth. A secchi disk is 20 cm (8 inches) in diameter, with alternating black and white quadrants. It is lowered into the water until it can no longer be seen by the observer. Light conditions, wind, and currents can affect accurate readings of the secchi disk. However, perhaps due to its simplicity and ease of use, the secchi disk is widely used in marine research and monitoring (Conversi 1992). Stormwater runoff after a rainfall event could cause lower secchi disk readings. Comparing secchi disk readings taken immediately after a storm with readings taken between storms would suggest that runoff is increasing turbidity and, therefore, resulting in shallower transparency reading.

The U. S. Virgin Islands Code requires a minimum of one (1) meter secchi disk depth for Class B and Class C waters. This is an extremely relaxed standard for tropical or subtropical waters. In many instances, a secchi disk can be seen to depths of 30 meters in U. S. Virgin Islands waters. If the secchi disk cannot be seen in 1 meter or more of water as a result of runoff from a construction site, construction activities should be stopped immediately until adequate mitigation measures and proper BMPs are in place.

Nephelometer/Turbidimeter

Turbidity is a second parameter of water clarity that can be easily measured in the field. Turbidity is a measure of the optical properties of water determined by estimating the amount of light scattered or absorbed by a sample rather than transmitted in straight lines. A turbidimeter, also called a nephelometer, measures the scattering effect that suspended solids have on a beam of light of a specific wavelength through a sample. This device sends an incident light beam in a single direction, and senses light scattered at a right angle to the incident beam. The higher the intensity of scattered light, the higher the turbidity. The U. S. Environmental Protection Agency has an approved method for measuring turbidity for regulatory for compliance purposes (USEPA Method 180.1; USGS 2000).

The U. S. Virgin Islands Code allows a maximum limit of three nephelometric turbidity units (3 ntus) in Class B and Class C waters. As with the secchi disk depth, this is a fairly relaxed standard for subtropical waters. If there is a turbidity plume from runoff from a construction site and turbidity is equal to or greater than 3 ntus, then construction activities should be stopped immediately until adequate mitigative measures and proper BMPs are in place.

Light Meters

Percent transmission of light is another measure of water clarity and can be attained by using a transmissometer. Wavelengths of light are naturally absorbed in marine waters as light travels through the water, with lower energy, longer wavelengths (such as red -- 660 nanometers) absorbed first. Dissolved, colloidal, and suspended particles in water cause further attenuation by absorbing and scattering the light. Transmissivity is the ability of water to transmit light along a straight path. Any incident light attenuated, scattered, or absorbed decreases the transmissivity of the water, thus more turbid or less clear water has lower transmissivity. A transmissometer sends an incident light beam in a single direction, and measures the light transmitted in that same direction. If the water contains a lot of foreign materials (solutes or turbidity particles), very little of the incident beam will reach the receiver because most of the light will be scattered away or absorbed by the foreign materials. However, if the water is very clear, most of the light will reach the receiver (Hydrolab Corporation 1998).

Other types of light meters that measure spectral transmission, scattering, absorption, and attenuation include radiometers and spectrophotometers. As with the other water clarity parameters, measurements of light scattering and attenuation are a function of the amount, size, and shape of particles in the water.

Temperature

Temperature can be measured fairly easily *in situ* by a thermometer, whether its a liquid-in-glass type or a thermistor thermometer. Temperature is often measured by a probe, which is part of a larger marine sampling instrument such as a CTD (an instrument that simultaneously measures conductivity [to determine salinity], temperature, and depth).

The U. S. Virgin Islands Code requires that temperatures shall not exceed an upper value of 90° F for Class B and Class C waters, and temperature changes more than 1.5° F from waste discharges shall not occur for Class B and Class C waters.

Salinity

Salinity is a measure of “the total amount of solid material in grams contained in one kilogram of seawater when all the carbonate has been converted to oxide, all bromine and iodine replaced by chlorine, and all organic matter completely oxidized" (Pickard and Emery 1982). Salinity is measured in practical salinity units (PSU), which replaced, and is equivalent to, the parts per thousand system (‰ = the number of grams of dissolved solids in one thousand grams of seawater).

One of the most common, simple, and accurate methods of determining salinity is to use a salinometer. As the salinity of water increases, the number of ions increases, and thus the sample can conduct more electricity. A salinometer measures the electrical conductivity of the sample (accounting for temperature) and converts it to salinity. Salinometers are extremely accurate, measuring salinity to better than 0.003‰ (Pickard and Emery 1982). As with temperature, salinity probes (i.e., which actually measure conductivity and convert to salinity) are typically part of a larger marine sampling instrument such as a CTD.

There are no territorial regulations for particular salinity levels in marine waters.

The salinity of the open ocean varies between 35-37‰. In coastal areas, freshwater inputs generally depresses salinity levels, with salinity gradients in estuaries and rivers ranging from 35‰ at the seaward side to <1‰ at the landward end. Conversely, salinity levels in salt flashes (usually in mangrove wetlands) can be extremely high.

The salinity of coastal waters in the U.S. Virgin Islands vary between 28-40‰, with most areas showing a mean of approximately 34‰. Concentrations at the two extremes are infrequent, and short-term occurrences would in all likelihood not impair ecological functions to any significant extent. As such, if salinity values for a site is lower than 25‰ or higher than 45‰, and a specific major source of input (e.g. stream, drainage outfall, etc.) has not been identified as being responsible, it is probable that a new source of effluent discharge has been established. In cases where values outside the limits set above are found, a more comprehensive search for a source of effluent discharge should be undertaken. However, it should be noted that such events can result from natural causes, primarily rainfall events, or conversely, when mixing in water bodies become negligible.

Dissolved Oxygen

Dissolved oxygen (DO) is a measure of oxygen gas dissolved in water. Sources of DO in water include atmospheric re-aeration and photosynthetic activities of phytoplankton, submerged aquatic vegetation, and other aquatic plants. Chemical, physical, and biological reactions can cause changes in DO concentrations.

The most common field method for determining concentrations of dissolved oxygen in marine waters is the amperometric method, which uses a temperature and salinity-compensating instrument that works with a polarographic membrane-type sensor. The permeability of the membrane is also a function of temperature.

The U. S. Virgin Islands Code requires that dissolved oxygen levels shall not be less than 5.5 mg/l for Class B waters and 5.0 mg/l for Class C waters.

pH

pH is a measure of the acidity or alkalinity of the water sample. Strictly speaking, it is a measure of the hydrogen ion concentration, and ranges from 1 (most acidic) to 14 (most alkaline), with 7 being neutral. The pH of water from the open ocean (and over coral reefs) ranges from 7.5 to 8.4, and varies only to a small extent with time. This small variation results from the buffering effect of seawater. However, in nearshore conditions, runoff from land often contains chemicals and other contaminants that change the pH in localised situations. This is particularly true after heavy rainfall events, and where storm drains channel runoff from urban areas. Additionally, in water bodies where there is little circulation (such as can occur in wetlands), the build-up of gases under anaerobic conditions can lower pH.

The most commonly used tool to measure pH is a simple pH meter.

The U.S. Virgin Islands Code requires that, for Class A waters, that there is no change in pH from existing (baseline) conditions. For Class B waters, the Code provides for a range of 7.0-8.3, and for Class C waters, a range of 6.7-8.5

SAMPLING PROTOCOLS

Model Sampling Scheme

In order to effectively monitor the conditions of marine waters adjacent to shoreline developments, four transects should be established. Three should radiate from the construction site, and one should be placed upcurrent of the site as a control (Figure 1). However, it should be noted a control transect may capture pollution from sources other than the construction site of interest.

Each of the four transects (including the control transect) should have a minimum of three stations, resulting in a total of 12 stations for each construction site. The first station along each transect should be in approximately one meter (3.28 feet) of water. Setting the station in that depth of water allows for easy correlation to the secchi depth standard established by the regulations. The second and third station on each transect should be approximately 5 meters (16.4 feet) and 15 meters (49.2 feet) seaward, respectively, from the first station (see Figure 1). Surface and bottom samples must be collected at each station. Stations should be added or transects modified to sample over seagrass beds or coral reefs that may be near the construction site, as these are the communities most sensitive to pollution. Therefore, the minimum sampling scheme should consist of the following:

- 3 transects + 1 control = 4 transects
- 3 stations per transect = 12 stations total
- 3 samples at the surface and 3 samples at the bottom of the water column per station = 72 samples total

Though the location of each sample station will be determined using a global positioning system (GPS), setting the transects requires the use of reference markers on shore. The simplest way to establish the transect is to place the boat in a straight line with two or more permanent landmarks on shore. If buildings and other structures are not available for this purpose, physical features of the land itself (headland, large rock, gut, etc.) can be used as landmarks. In either case, using a compass to set the bearings (of the landmarks from the boat) will enhance in the precision of the exercise, and make it easier to relocate the transect on future visits. Once the transect has been set, the GPS is then used to determine the coordinates of each station. The landmarks must be set and recorded, as they may be required to find the sample stations in the event the GPS malfunctions on a future sampling event.

The above guidelines refer mainly to construction on land. Marine-based construction activities (pier, dock, marina, groyne, etc.) are peculiar cases, which almost invariably will create impacts that exceed the water quality standards. Such impacts could result from factors such as disturbance of bottom sediments or discharge of a pollutant (concrete, paint, etc.) into the water. Where construction activities are based in the marine environment, the monitoring will be much more rigorous and sampling events more frequent. In such cases, the location of the sample stations should ensure that some stations coincide with a minimum of 25% of the sample stations established by the project proponent as part of their water quality monitoring plan. Where possible, a number of sample events should be conducted jointly between DPNR-CZM and the project proponent.

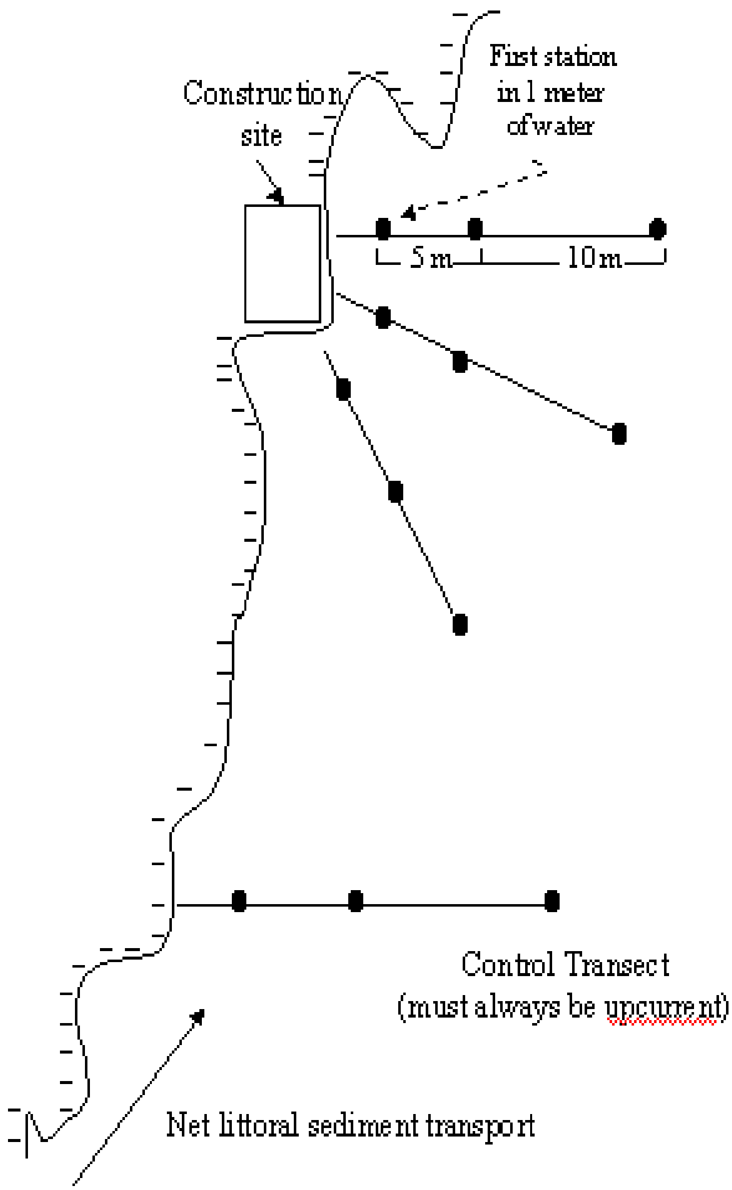
Frequency of Measurement

Sampling should be performed at least once before construction begins during both dry and wet weather (after a rainfall event of 1 cm (0.4 inches) or greater, at least once during dry weather during construction, and every time after a rainfall event of 1 cm or more. Based on information from previous studies and reports (Bortman 1997; Wernicke 1986; Smith and Ajayi 1983; Purcell 1980), it is assumed that on average, stormwater runoff will occur from rainfall events of 1 cm or greater in the U. S. Virgin Islands. Post-construction sampling should also be performed at least once during both dry and wet weather (after a rainfall event of 1 cm or greater). If rainfall greater than in trace amounts but less than 1 cm occurs on more than three consecutive days, then stormwater runoff may occur on subsequent days with continued rainfall of less than 1 cm. It should be up to the discretion of DPNR to qualitatively evaluate soil moisture conditions and decide if sampling should occur with subsequent rainfall on the fourth day regardless of how much rain has fallen that fourth day. Therefore, the minimum frequency of sampling should consist of the following:

- Once pre-construction during dry weather
- Once pre-construction after rainfall $\geq$ 1 cm
- Once during construction during dry weather
- Every time after rainfall $\geq$ 1 cm during construction
- Once post-construction during dry weather
- Once post-construction after rainfall $\geq$ 1 cm

If any of the water quality parameters sampled exceed Territorial standards (page II-4), construction activities should be immediately stopped until proper measures are put in place to prevent further water quality impacts. Examples of actions that should be taken to prevent further water quality impacts include modifying existing best management practices (BMPs) or installing new BMPs to address the problem.

Figure 1: Sampling Scheme



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IV. QUALITATIVE PARAMETERS

INTRODUCTION

The U.S. Virgin Islands Code requires that marine recreational waters shall meet generally accepted aesthetic qualifications and shall be free of substances or wastes such as floating debris, oil, scum, substances producing objectionable color, odor, taste, or turbidity, and materials in concentrations which are toxic or which produce undesirable physiological responses in humans, fish, and other animal and plant life.

One of the most important ways to monitor whether construction activities may be impacting marine waters is to visit the site and observe the water firsthand. Is there anything unusual observed at the site or in the nearby marine waters? Is there a plume of any kind? Can it be traced to the site? Is it obvious why a plume may be occurring? Is there an oily sheen on the surface of the water? Are there any strange odors? Is the water an unusual color? Is there a fish kill or unusual mortality of other marine species in the area? Is there debris or any kind of floatable material in the water? Although they may not correspond with particular water quality regulations per se, all of these questions should be considered when monitoring marine waters adjacent to construction activities. The questions raise important concerns that may warrant further investigation by DPNR staff and possibly result in a halt in construction activities until a thorough investigation is performed and adequate mitigative measures and proper BMPs are in place.

A list of these qualitative parameters has been included in the sample data recording template created as part of this manual (Appendix 2).

DESCRIPTION OF POSSIBLE OBSERVATIONS

Stormwater Run-off

The most obvious source of pollution to marine waters from a construction site is stormwater runoff. If stormwater runoff can be seen discharging to marine waters, then DPNR staff should set up monitoring transects as illustrated in Figure 1, with the transects starting from the site of stormwater input for collecting samples for analyses as described in Chapter 3.

Turbidity Plume in the Water

Turbidity plumes can be due to a number of physical factors not related to construction activities, such as wind or a storm re-suspending bottom sediment or boat propellers. It is important to try to trace a turbidity plume to its source. Can the turbidity plume be traced to stormwater runoff from a construction site? The plume should be observed over a period of time (i.e., 5 to 10 minutes). Is the plume dissipating over time? Can the source be identified after a period of observation? If there is a suspicion that turbidity is coming from runoff from a nearby construction site, then sampling should occur as described in Chapter 3 and shown in Figure 1.

Unusual Odors Emanating From the Site or Nearby Marine Waters

Unusual odors can be due to a number of reasons:
1. A chemical release of some kind (i.e., certain pesticides, fungicides, rodenticides, etc.);
2. Cleaning solvents or other chemicals associated with construction;
3. Oil or gas;
4. Sewage; or
5. fish kills.

As with a turbidity plume, the first step is to try to identify the source. If the source is a construction site, then measures must be immediately put in place at the construction site to stop the objectionable activity and prevent any recurrence.

Oily Sheen on the Surface of the Water

It is extremely important to identify the source of any oil, gas, or grease found floating on the surface of the water. If an oily sheen on the surface of the water is from oil, gas, or some other form of hydrocarbon leaking from the site, immediate measures need to be taken to stop the leaking. Appropriate oil spill response protocols established by DPNR would need to be followed to address the oil already in the water. As with all sources of contaminants, it is important to verify whether the presence of any hydrocarbon pollutant in the water is from a construction site or another possible source, such as a boat or other kind of motorized craft.

There can be instances after a rainfall event when stormwater runoff containing petroleum hydrocarbon pollutants makes its way to marine waters from roads or other land-based sources different than a construction site. If this is the case, then samples should be collected, and if DPNR staff determines that there is a significant quantity of oil, then appropriate oil spill response protocols should be followed.

Fish Kill or Unusual Mortality of Other Marine Species in the Area

Fish kills or mortality of other marine species in large numbers can be due to toxic chemicals or low dissolved oxygen. Toxic contaminants could possibly be from chemical releases from a construction site. This would be difficult to determine until the fish or other dead marine organism underwent pathological analyses to assess cause of death.

There could be instances where there are large amounts of organic material in runoff coming from a construction site that was recently cleared, or from sewage from a land-based source. The decomposition of the organic material could lead to excessive biochemical oxygen demand, thereby lowering oxygen levels and stressing marine organisms, which in extreme cases, could lead to large-scale mortality of marine organisms.

The source of a fish kill or any large scale mortality event is more difficult to assess. However, it is important to investigate the source in order to prevent it from recurring.

Algal Bloom (Phytoplankton) or an Unusual Amount of Macroalgae in the Area

Conditions of low oxygen (hypoxia) can also occur from the decomposition of an algal bloom or large amounts of macroalgae. An algal bloom or an unusually large amount of macroalgae would result from a significant input of nutrients (i.e., nitrogen and/or phosphorus), such as from fertilizer or contained in sediment. An algal bloom would change the color of the water from blue or blue-green to more of a green color. Depending on the type of algal bloom, the water could even look greenish brown.

The decomposition of an algal bloom or large amounts of macroalgae could lead to excessive biochemical oxygen demand, thereby lowering oxygen levels and stressing marine organisms, which, in extreme cases, could lead to large-scale mortality of marine organisms.

If the source is the construction site, then steps should be taken to properly store the materials causing the contamination, as well as preventing surface runoff (containing the contaminant(s)) from draining from the site.

Debris or Other Kind of Floatable Material in the Water

The presence of plastic or construction material of any kind is more aesthetically displeasing than a potential threat to marine biota. However, there is well documented evidence that balloons, rope or line, and plastic straps and bags may be a threat to marine mammals, sea turtles, and shorebirds. Other materials, such as wood, could possibly become a navigational hazard. Proper handling of construction materials would ensure that none of the material is either blown off-site into marine waters or carried to marine waters in stormwater runoff.

Where such infractions occur, the objectionable material should be collected and disposed of properly. Steps should then be taken to ensure appropriate containment and/or disposal of such materials.

It may be difficult to pinpoint why coastal waters look unusual. However, it is important to note any changes and investigate further through sampling and observation. Trying to identify the source of change is critical to resolving water quality concerns. Familiarity with the area and regular monitoring will aid in catching potential water quality problems early.

V. SUMMARY OF BEST MANAGEMENT PRACTICES

INTRODUCTION

Stormwater runoff and erosion are natural processes that occur in the environment. Development activities alter the landscape by removing vegetation and increasing impervious surfaces, thus changing the quality and quantity of stormwater runoff. This change in stormwater runoff can lead to adverse impacts to coastal waters. If appropriate erosion and sediment control measures are not used, then sediment, along with attached soil nutrients and organic matter, can be delivered to coastal waters (Wright *et al*. 1995). Some pollutants, such as nutrients, heavy metals, and hydrocarbons, can also attach to sediments and end up in coastal waters (Shueler 1987).

Most of the land in the Virgin Islands is steep and very susceptible to soil erosion. As more land becomes developed throughout the Virgin Islands, it is becoming increasingly evident that future developmental pressure is going to be on steeper, more erodable soils, making the establishment and implementation of best management practices (BMPs) more important than ever. Therefore, the first step prior to any construction activities is the development of a stormwater, erosion, and sediment control plan specifically designed for a construction site (Wright *et al*. 1995). These plans should include steps to control pollutants in stormwater runoff during (1) siting and design, (2) construction, and (3) post-construction activities/phases.

This chapter will focus on BMPs that can be used to minimize impacts to coastal waters. However, it is also important to follow basic management practices in order to control pollutants in stormwater runoff. Basic management practices include proper storage, handling, and disposal of building materials, construction site waste, fertilizers and hazardous materials (e.g., paints, cleaning solvents, concrete curing compounds, pesticides, herbicides, fungicides and rodenticides), and the development of a chemical spill prevention and control plan (Wright *et al*. 1995).

It is important to note that although a number of BMPs have been developed and refined to mitigate adverse impacts associated with development activity, each BMP has both unique capabilities and persistent limitations (Schueler 1987). No single BMP can be applied to all development situations, and all BMPs require careful site assessment prior to design (Schueler *et al*. 1992). In fact, in the report titled, "A Current Assessment of Urban Best Management Practices, Techniques for Reducing Nonpoint Source Pollution in the Coastal Zone," Schueler *et al*. (1992) recommend that screening tools should be followed to determine which is the best BMP prior to, during, and after construction. Screening tools consist of identifying:
- BMPs that are feasible based on the physical constraints of the site;
- Stormwater benefits provided by each BMP option;
- Relative pollutant removal capability of BMPs; and
- Natural or human amenities provided by the BMP.

In many cases, multiple techniques may be needed to address possible impacts of stormwater runoff. Best Management Practices fall into two general categories, stabilization practices and structural practices.

STABILIZATION PRACTICES

Stabilization practices rely on vegetation to anchor the soil. Preserving existing vegetation by clearing land only where structures will be sited, or re-vegetating disturbed soil as soon as possible after construction, is the most effective way to control erosion (Wright *et al*. 1995). If clearing is limited to only where structures will be sited, then earthwork and stormwater, erosion, and sediment control costs can be sharply reduced, by as much as $5,000 per acre (Brown and Caraco 1999). Natural vegetation provides a buffer to slow runoff and filter sediment. Using native species rather than exotic plants has proven to be most successful. The Virgin Islands Environmental Protection Handbook (Wright *et al*. 1995) recommends that stabilization practices should be initiated as soon as practicable in sections of a site where construction activities have temporarily or permanently ceased, but in no case more than 14 days after cessation of activities (Wright *et al*. 1995).

Other stabilization practices include filter strips, land grading, surface roughening, seeding and planting, mulching and matting, soil retaining walls, and soil bioengineering. All of these options are described in further detail in the Virgin Islands Environmental Protection Handbook (Wright *et al*. 1995), thus only a brief summary of relevant measures will be provided here.

<u>Filter strips</u> are vegetated strips of land that can be used either temporarily or permanently to control stormwater runoff to coastal waters. It can be a vegetated area that is left undisturbed or a newly planted area.

<u>Land grading</u> is the alteration or reshaping of the existing site topography to improve drainage and control erosion and stormwater runoff.

<u>Mulching</u> uses cut grass, wood chips, wood fibers, straw, or gravel to temporarily stabilize an area and reduce the speed of stormwater runoff. It can aid in the establishment of vegetation by holding seeds, fertilizer, and topsail in place, as well as holding moisture and insulating against high temperatures. <u>Mulch mattings</u> are sheets of mulch using jute or other wood fibers that provide more stability than loose mulch. <u>Filter fabrics</u> and other synthetic, geotextile materials can be used for erosion control, particularly in areas of steep slope where mulching could be washed away.

<u>Seeding and planting</u> can be used for temporary or permanent sediment stabilization and runoff control. Temporary seeding relies on fast-growing grasses. Permanent seeding or planting uses tress, shrubs, grasses, legumes, and vines on highly erodable areas of a site.

<u>Soil retaining walls</u>, which could arguably fall under the structural practices, hold loose, unstable soil in place. They can be built for temporary or permanent erosion control and safety at a site. Soil retaining walls should be used in areas where vegetative cover cannot stabilize a slope.

<u>Soil bioengineering</u> consists of either using a combination of rock and vegetation such as vegetated rock gabions or vegetated rock walls to provide sediment stabilization and prevent erosion or use of more rigid non-living structures such as gravity retaining walls and rock buttresses.

<u>Surface roughening</u> employs the use of horizontal grooves running across the slope, stair stepping or tracking with construction equipment to reduce stormwater runoff velocity, reduce erosion and trap sediment, increase infiltration and aid in the establishment of vegetative cover. Slopes steeper than 33 percent (3:1) require surface roughening to facilitate stabilization by grass, plants, trees, shrubs and other vegetative cover.

The value of soil stabilization in any form cannot be over-emphasized. Research in the state of Maryland and other areas has shown that it can reduce sediment concentrations by up to six times, compared to exposed soils without stabilization (Brown and Caraco 1999). Further studies have found that seeding and various mulches on construction site soils can reduce sediment erosion by about 80 to 90% (Brown and Caraco 1999). A good construction plan should also include a contingency line item for replacing temporary cover in the event that the cover does not take (drought, poor germination, weather, etc.) (Brown and Caraco 1999).

STRUCTURAL PRACTICES

Structural practices can be used as temporary or permanent structures to control sediment erosion and stormwater runoff quantity and quality. There are numerous structures that can be put in place before, during, or after construction. These include:

- Berms;
- Check Dams;
- Gabion Inflow Protection;
- Outlet Protection;
- Ponds and Basins;
- Porous Pavement;
- Sand Filters;
- Sediment Traps;
- Silt Fences;
- Swales;
- Trenches; and
- Water Quality Inlets/Oil Grit Separators.

Many of these options are described in further detail in the Virgin Islands Environmental Protection Handbook (Wright *et al*. 1995) and Schueler *et al*. (1992), and only brief summaries are here provided.

<u>Berms</u> made of loose gravel, stone, crushed rocks, or cut brush are temporary ridges that can slow and filter stormwater runoff. Berms can also be used to divert runoff to a stabilized outlet (Wright *et al.* 1995). The steeper the slope, the closer berms should be placed together. Berms have a limited lifespan and therefore they should be used only as a temporary measure. Filter berms can clog, and therefore they need to be regularly inspected. Brush filter berms have been used successfully in the U. S. Virgin Islands to control overland flow, not for concentrated flow from channels, swales and guts (Wright *et al.* 1995).

<u>Check Dams</u> are constructed across a drainage ditch, swale, or channels to reduce the speed of stormwater runoff. Reduced stormwater runoff results in reduced erosion and increased sediment deposition. Check dams can either be permanent or temporary in nature. Check dams are appropriate in channels where vegetation cannot be established. Check dams are not recommended in streams or guts because they block normal stream flow can increase the potential for erosion (Wright *et al*. 1995). The maximum drainage area of check dams should not be greater than two acres. Sediment and/or debris should be removed regularly and check dams should be inspected for signs of erosion at the edges.

<u>Gabion Inflow Protection</u> are rock or concrete-lined drainage ways that are used as temporary measures to convey concentrated stormwater runoff to sediment traps, basins, or ponds to prevent erosion of channels or embankments (Wright *et al.* 1995).

<u>Outlet Protection</u> commonly consists of a rip rap apron that is installed at the end of a stormwater runoff pipe, dike, swale, culvert or channel to reduce speed and energy of stormwater runoff and erosion. Outlet protection should be considered at the outlets of ponds and sediment basins. Tailwater depth, apron size, bottom grade, materials, etc. are functions of slope and follow specific design specifications (see Wright *et al.* 1995). The maintenance requirement is low. However, inspections should be performed regularly to check for erosion, scouring of rip rap, and clogging debris.

<u>Ponds</u> consist of a basin or series of basins that can hold stormwater runoff after a rainfall event, allowing for pollutants to settle out. Conventional extended detention ponds are normally dry between rainfall events. Wet ponds have a permanent pool of water (Schueler *et al*. 1992). Multiple ponds can employ a combination of dry and wet ponds, along with shallow wetlands or infiltration. Clogging can occur in ponds, therefore maintenance of these ponds is essential. This may not be the best choice for the Virgin Islands, at least in St. Thomas and St. John, given the islands' shallow soil layer.

<u>Porous Pavement</u> diverts stormwater runoff through a porous asphalt layer to an underground stone reservoir, whereby the runoff gradually infiltrates into the subsoil. The major disadvantage of this BMP is its high failure

rate (75%) due to clogging. It also needs to have at least three feet of soil with an infiltration rate greater than 0.5 inches per hour and on slopes less than five percent (Schueler *et al.* 1992).

Sand Filters focus on capturing the first flush of stormwater runoff, whereby the runoff is diverted into a self-contained bed of sand. The stormwater runoff is strained through the sand, collected in underground pipes, and diverted to a stream, channel, or water gut (Schueler *et al*. 1992). Often sand filters have layers of peat, limestone and/or topsoil and may also have a grass cover. Sand filters have excellent longevity. Nevertheless, relatively simple but frequent maintenance (primarily raking, surface sediment removal, and removal of trash and debris) is required to sustain high performance. They are good for small sites and in areas with thin soils, high evaporation rates, low soil infiltration rates, and limited space such as on St. Thomas and St. John.

Sediment Traps consist of temporary ponds, or installation of an earthen embankment across a low area or drainage swale with an outlet or spillway to slow the release of stormwater runoff. The trap is designed to hold stormwater runoff long enough for the sediment to become deposited. Sediment traps are only for small areas (typically 5 acres or less). Because of the predominance of clay soils in the U. S. Virgin Islands, sediment trap basins should be at least 3,600 ft^3 to allow for the fine-grained particles to filter out. However, some very fine silts and clays may not be removed from the stormwater runoff (Wright *et al.* 1995). Sediment traps require periodic removal of sediment and are only effective if properly maintained. Once construction is complete and a site is stabilized, sediment traps should be removed, the area graded, and stabilized with vegetation (Wright *et al.* 1995).

Silt Fences are temporary structures to reduce the speed of stormwater runoff and prevent sediment from small areas (< 5 acres) entering coastal waters. Silt fences should not be constructed in guts or swales. Silt fences are not recommended at the toe of slopes because they may be unable to prevent high velocity stormwater movement. Test plot studies in Oregon found performance of silt fences at the toe of slopes to range from only 36% to 65% (Brown and Caraco 1999). Stormwater may erode a channel beneath a fence and therefore they need to be frequently inspected with prompt maintenance in order to be effective. Proper installation and appropriate pore size of the filter fabric are important to the effectiveness of silt fences.

Swales, such as grassed swales, are earthen conveyance systems in which pollutants from stormwater runoff are filtered through the grass and soil. Enhanced swales use check dams and wide depressions to increase storage of stormwater runoff and increase settling of pollutants (Schueler *et al.* 1992). Conventional grassed swales can last for an indefinite period of time if properly designed, periodically mowed, and maintained. However, Schueler *et al*. (1992) recommend that grassed swales should not be used for construction stage runoff because high sediment loads from unstabilized construction sites can overwhelm the system. Monitoring of pollutant removal indicates mixed results, with some systems showing moderate to high pollutant removal and other systems showing no removal capability (Schueler *et al.*1992). Highest removal rates of pollutants by swales are found in warmer climates, such as the U. S. Virgin Islands, where the climate supports significant vegetation year-round.

Trenches are typically shallow, excavated depressions that have been backfilled with stone to create an underground reservoir. Stromwater runoff that is diverted to trenches gradually percolates from the bottom of the trench to the subsoil. Some trench systems have pre-treatment systems to remove sediment and oil (Schueler *et al.* 1992). Trenches tend to have a short lifespan. They are more successful in arid climates and in regions where soils are predominantly clay or silts like the U. S. Virgin Islands. However, effectiveness of trenches is sharply reduced if slopes are greater than five percent. Like ponds, trenches have a tendency to eventually clog and are in need of regular maintenance.

Water Quality Inlets/Oil Grit Separators are underground retention systems specifically designed to remove heavy particulates (coarse-grained sediments) and absorb hydrocarbons from stormwater runoff. Silt and clay sediment removal is minimal. Water quality inlets are best for small, highly impervious areas such as gas stations, parking lots and convenience stores. These are costly systems and require quarterly clean-outs. However, no acceptable clean-out and disposal techniques exist, and maintenance is therefore virtually impossible.

The top 10 ways to ensure effective control of sediment erosion and stormwater impacts on coastal waters are to:

1. Minimize needless clearing and grading;
2. Protect waterways and stabilize drainageways;
3. Phase construction to limit soil exposure;
4. Immediately stabilize exposed soils;
5. Protect steep slopes and cuts;
6. Install perimeter controls to filter sediments;
7. Employ advanced sediment settling controls;
8. Certify contractors on stormwater, erosion, and sediment control plan implementation;
9. Adjust stormwater, erosion, and sediment control plan at construction site; and
10. Assess stormwater, erosion, and sediment control practices after storms.

RESPONSE PROTOCOLS TO PROBLEMS

Responses to water quality violations can be triggered in one of three ways:

1. The person implementing the environmental monitoring plan for the developer may determine that there is a problem, and take the necessary corrective action. Corrective action may or may not involve the temporary cessation of construction activities. Similarly, the process may or may not involve notification of DPNR. Given this level of flexibility, it is best that response protocols be identified in the environmental monitoring plan, and included as part of the permit. This latter precaution is more important for construction activities taking place in the sea.

2. The DPNR staff person conducting a site inspection notices a problem and initiates the appropriate response. Whether or not the infraction warrants the cessation of construction activities, the problem should be brought to the attention of the senior site manager. This should be followed by, at a minimum, a written report to the developer, said report containing all the pertinent information (date of inspection, time problem was noted, nature of the problem, site manager notified, response, follow-up required, etc.). Where the problem is deemed to be significant (creating a major environmental or water quality impact), the level of impact should be determined if possible, and construction activities ceased until the problem is resolved. This may require additional DPNR staff resources being called to the site. Certainly, photographs should form part of the records when dealing with major problems. Additionally, if the problem creates an impact on the marine environment, water samples should be taken to determine the resulting level of change, if any, ion the monitoring parameters. As before, it is best if DPNR monitoring/inspection requirements and procedures form part of the permit for the development.

3. If the results of the water quality monitoring show that there is an increase in the concentration of the parameters above baseline conditions, then action can be initiated. However, in such a case, the person conducting the monitoring must determine that there is reasonable probability that the change in water quality is caused by the construction activities in question.

Where the violation is deemed to be significant, not only should construction activities be stopped, temporary BMPs can be put in place to respond immediately to the problem. Examples of temporary BMPs include berms, sediment traps, silt fences, check dams, and temporary sediment basins. All of these BMPs are described previously in this chapter.

It is important to emphasize that proper BMPs are the best preventive measures to protect water quality. It is far easier, requires less effort, and is less costly overall to ensure that appropriate BMPs are in place and are working properly at a site under development, than to respond once a water quality concern exists (see Appendix 3 for model sampling trip).

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VI. INSTRUMENTATION

INTRODUCTION

The following list of equipment was selected to fulfill the needs of the Department of Planning and Natural Resources, Division of Coastal Zone Management (DPNR-CZM) for a water quality monitoring program, which will be used as part of the monitoring of construction activities related to development projects carried out in the coastal zone. The primary objective is to use a suite of field instruments to establish baseline water quality conditions and to obtain rapid measures of water quality following heavy rainfall events. These water quality data are used to ensure compliance with conditions set as part of the coastal zone construction permit. The field instruments to be used in this water quality monitoring program are:

- A secchi disk – for checking water clarity;
- A turbidimeter – for measuring the level of suspended solids;
- A hydrocarbon test kit – for checking the presence of dissolved dispersed hydrocarbons;
- A pH meter – for measuring pH;
- A YSI multi-parameter water quality meter - for measuring dissolved oxygen, salinity, and temperature; and
- A Van Dorn Bottle – for collecting the water sample.

An automatic digital rain gauge and handheld global positioning system (GPS) unit will be used in conjunction with the other water quality equipment to identify significant rainfall events and to locate sampling stations, respectively.

In addition to ensuring compliance with local water quality standards, measuring sea surface temperatures will be useful for documenting warm-water anomalies, which may trigger regional coral bleaching events. This information is useful for separating out the effects of human impacts from development activities versus natural disturbances.

Standard operating procedures should include a stable operating platform and the careful deployment of all instruments that are lowered over the side of the vessel. Care should be taken that instruments do not impact the bottom, which may damage corals and probes of sensitive instruments, or that lines and electrical cables do not become entangled on the reef or in the boat propeller. A supply of distilled and fresh water is necessary on each sampling mission for rinsing equipment between samples and at the end of each day. Several one liter plastic bottles should be included in field equipment to receive contents of Van Dorn bottle and to take water samples back to laboratory for analysis if desired.

Secchi disk

Specifications: A 20 cm acrylic plastic disk with black and white quarters, stainless steel hardware, 20m of line on spool, weighted underneath (Wt. = 5.0 lbs).

General Description and Conditions for Use: The Secchi disk is a simple device used to measure water column transparency or the depth to which one may see into the water (i.e. visibility). The Secchi disk consists of a weighted circular plate, 20 cm in diameter, with the surface painted with opposing black and white quarters. It is attached to a calibrated line by a ring at the center so that it hangs in the water horizontally. Since visibility into the water varies with time of day and eyesight of the observer it is recommended that the same person use the Secchi disk at same time of day (Lind 1985). The Secchi disk must be used from a stationary platform (i.e. anchored boat) with no significant current present. If a current is present more weight can be added to the bottom of the Secchi disk to reduce instrument drift. When using the Secchi disk lower it gently into the water. Do not drop or throw the disk from the deck of the boat as the force of the impact with the water surface may crack or shatter the acrylic disk.

Standard Operating Procedure: To determine water visibility depth.

1. Lower the Secchi disk slowly, counting the black meter marks.
2. Record the depth from the calibrated line once you are no longer able to distinguish between the black and white quadrants.
3. Lower the disk farther until it is completely out of sight.
4. Then raise it slowly until the black and white quadrants become distinguishable.
5. Record depth again from the calibrated line.

The average of these two readings is taken for the final Secchi disk visibility depth (Lind 1985). If the Secchi reaches the sea floor and is still visible, record the depth followed by the letter "B" to designate bottom. Since cloud cover, position of the sun, roughness of the water and observer can all influence the Secchi disk reading, these environmental conditions should be recorded along with visibility depth data. It is important for the observer to establish a set of standard operating conditions that will be used every time. For example, always take readings while standing, with or without sunglasses, on the lee side of the boat, with the sun to the observers back, sometime between 9 am and 3 pm.

Calibration: None

Maintenance: Rinse Secchi disc and calibrated line with fresh water at end of each day. The line should be washed and hung out loosely to dry in the open air.

2020 LaMotte Turbidimeter

Specifications: Compact field 2020 turbidimeter, EPA accepted for NPEWR & NPDES, portable, 9V battery, range 0-1100 NTU, $\pm$2% accuracy below 100 NTU and $\pm$3 above 100 NTU, with three manual ranges: 0.0 to 10.99, 11.0 to 109.9 and 110 to 1100 NTU.

General Description and Conditions for Use: The turbidimeter measures dissolved organics and suspended solids. Nephelometric turbidity measurements depend on the detection of light scattered from particles suspended in the liquid. Proper measurement techniques are important in reducing the effects of instrument variation. To insure more accurate and repeatable measurements the analyst must insure that samples are processed immediately to prevent temperature changes and settling of suspended particles. Precise measurements for very low turbidity samples, such as tropical waters, require using a single sample vial for all measurements. Using one vial provides the best precision and repeatability. Ensure that the vials are extremely clean and free of scratches and the sample is free of air bubbles during measurements. Applying a thin coat of silicone oil will mask minor imperfections and scratches, which may contribute to turbidity by scattering light. When taking measurements do not hold the instrument in your hand but place it on a flat, steady surface. Make sure that the cap of the sample cell is tightly secured to prevent spillage of sample into instrument and that the sample compartment lid is closed to prevent stray light from entering testing chamber during measurement. Avoid operating in direct sunlight or rain. Vibrations and electric fields around motors can affect readings.

Standard Operating Procedure:
In light of the fact that a turbidimeter does not always provide an accurate measure of total suspended solids, this limitation can be partially overcome with a rigorous sampling design. Establish a minimum of 8 sampling stations that will provide a detailed picture of the coastal area that may be impacted (i.e. sampling stations positioned both parallel and perpendicular to shoreline). Establishing a baseline at this location prior to land development. Conduct frequent monitoring (at least once per hour) during and after significant rainfall events.
Once sample has been collected

1. Fill a clean sample vial to the fill line, cap, and wipe with a lint-free cloth (lens paper or lint free wipes (i.e. Kimwipes) also work well).
2. Apply small amount of silicone oil, spread evenly over vial surface then wipe off excess with lint free wipes. The vial should appear nearly dry with little or no oil visible. Handle the vial by the cap only to eliminate water droplets and fingerprints on glass surface.
3. Insert sample vial into the sample compartment using the orientation mark.
4. Press “READ” and the turbidity measurements will be displayed in about 13 seconds as NTU units.
5. To turn off, press “READ” until OFF is displayed, then release the button.

Calibration: The 2020 turbidimeter has been pre-calibrated. The meter does not need to be re-calibrated by owner. However, the calibration needs to be standardized. The 2020P turbidimeter is based on formazin, the primary standard for turbidity. To obtain the most accurate readings the turbidimeter must be properly calibrated with a primary standard once a week as required by regulations and laws for compliance monitoring. To do this, select a LaMotte AMCO 2020 standard in the range of the samples to be tested.

1. Pick one of the standard bottles to do first (10.0 or 1.0 sample).
2. Put the cap on and wipe the tube clean with lint free wipes.
3. Open the lid of the meter and slid the tube in, making sure to align the arrow marks.
4. Close the lid and press “READ”

If the display value is not the same as the value of the standard:

5. Push the “CAL” button for 5 seconds until CAL is displayed.
6. Release the button and the display will flash.
7. Use the up/down arrows until the value of the standard is displayed.
8. Push the “CAL” button again to save the calibration. Calibration is complete when the display stops flashing.

Maintenance: Keep the turbidimeter and accessories as clean as possible. Wipe salt spray and sample spills from instrument surface with a moist cloth and dry with a clean towel or use lens paper. Avoid prolonged exposure to direct sunlight or ultraviolet light and store in carrying case when not in use. Wash sample vials with a mild, non-abrasive detergent, rinse with distilled water and air dry. Avoid scratching cells and wipe all moisture and fingerprints off vials before inserting them into the instrument. Remove batteries if instrument is stored for periods greater than one month. AA alkaline batteries typically last for about 300 tests with the signal averaging option off and about 180 tests with the signal averaging on. The battery icon flashes when battery power is low. Keep spare batteries in carrying case at all times to ensure continuous operation in the field. If the lamp bulb burns out, call the manufacturer (LaMotte Company 1-800-344-3100 or fax 1-410-778-6394). Recalibrate with the standard after lamp replacement.

Digital Rain Gauge

Specifications: Rain Collector II, HOBO Event Rainfall Logger, and BoxCar Software, records up to 20 in. to nearest 1/100 in. (rain collector), records and stores rainfall amounts and time event occurred up to 80 in. (HOBO). Rain collector comes with 40 ft telephone cable and HOBO comes with 6 ft cable lead. BoxCar comes with an interface cable and manual. HOBO logger is in a waterproof case. BoxCar software allows access to and downloading of stored data. HOBO requires a CR-2032 (lithium) battery, which provides one year of continual use. Wt. 2.8lbs total.

General Description and Conditions for Use: The Rain Collector measures and logs rainfall, and must be set up within the watershed of the development being monitored on a level location sheltered from strong wind and clear of overhangs and tree branches. Use the leveling trough in the bucket to make sure the bottom is on a level surface. Ensure that the rain gauge is easily accessible for normal cleaning and that there is an unobstructed path for water runoff from the drain screens. A magnet-operated switch in the Rain Collector II may not work properly if mounted on or near an object that attracts magnets (i.e. steel fence). The HOBO Event Rainfall Logger is in a weatherproof case that should be placed out of direct sunlight. It can be located with in 6 ft of gauge or mounted in the bucket.

Standard Operating Procedure:
The Rain Collector will collect and drain the rain automatically. The HOBO Event Rainfall Logger will store up to 80 in. of rainfall data in any given time frame. The HOBO has a red LED (Light Emitting Diode) that blinks every two seconds while it is logging. The light also blinks four times rapidly as it stores an event. A regular time interval needs to be established to download the data when the 80 in. maximum is not exceeded (i.e. once a month). The data can be downloaded as follows:

1. Detach the logger from the rain gauge and take to the computer of choice OR a portable computer can be taken to the logger at the site.
2. Hook the logger up to the computer via an interface cable so the data can be downloaded using the BoxCar software.
3. Upon replacement of the Logger, maintenance to bucket should be done if needed.

Please refer to the guide that is included with the software for downloading and operating procedures.

Calibration: The Rain Collector requires only a flat, level surface. Calibration for the collector is done at the factory so the bucket tips (and records rainfall) for each 0.01 in. of rain. It is possible to adjust the calibration slightly. If this needs to be done refer to Rain Collector guide.

The HOBO logger will be calibrated when set up occurs with the BoxCar software. It has a feature that causes it to ignore events for a programmable period after an event is recorded. The lockout time can be set for one second to as long as nine hours. Since the logger is being used with the Rain Collector II the lockout time should be set for one second. This is important because every time the logger is disconnected from the bucket, it will record it as an event. The shorter the lockout time the less likely there will be any delay in data collection.

The BoxCar software can be downloaded from the disk provided. Before starting BoxCar, make sure that the computer’s clock is set to the correct time. The Logger uses the computer’s clock to set its own internal clock. Refer to software guide for additional instructions.

Maintenance: The Rain Collector II should be cleaned at least once or twice a year.

1. Disconnect the collector cable.
2. Separate the cone from the base.
3. Use warm soapy water and a soft cloth to clean pollen, dirt, and other debris from the cone, cone screens, and bucket.
4. Use a pipe cleaner to clear the funnel hole in the cone and the drain screens in the base.
5. When all parts are clean, rinse with clear water.
6. Reattach the cone and replace the screen.
7. Reconnect the rain collector cable.

The HOBO Logger needs the battery to be replaced at least once or twice a year.

1. Open the case (in a protected area) by unsnapping the latch and lifting the lid.
2. Unplug the 2.5mm sensor cable
3. Hold the case upside down by the bottom and firmly tap the open case into the palm of your hand until the circuit board dislodges. Do not hold the case by the top or you may snap the lid off.
4. Remove the circuit board from its cover and then remove the battery by carefully pushing it out with a small, blunt instrument.
5. Install a new battery with its printed side away from the HOBO's circuit board.
6. The light will blink three times after the battery has been installed correctly.

The data logger case is weatherproof when closed and latched. The electronics need to be protected from rain and condensation. If the electronics get wet, remove the battery immediately and dry the board completely with a hair dryer before reinstalling the battery. The moisture-absorbing pack inside the case should be replaced when the battery is changed.

Magellan GPS 310 Handheld

Specifications: latitude/longitude, speed, distance, track, bearing, cross-track and off-course error, waypoints, 24 hr, 2 AA batteries, waterproof, floats.

General Description and Conditions for Use: Records fixed positions to within 15 m, and velocity to 0.12mph. Must be outside and away from overhangs or large structures for accurate reading. The GPS will save ten way-points and one route with up to ten reversible legs as well as navigate to 100 saved locations. Three navigation screens show bearing, heading, distance, speed, direction, steering, time to go, cross-track, elevation, and time and satellite elevation. The re-settable trip odometer allows time and distance to be estimated.

Standard Operating Procedure: Use to establish and relocate permanent monitoring stations. Before sample sites are saved as landmarks (LMK), the home point should be saved (ex: boat dock or channel marker).

1. After GPS is on, press "MARK".
2. To name the landmark, use the UP/DOWN arrows to change the character and the LEFT/RIGHT arrows to move the cursor to the left or right respectively. Use a unique four-letter code for each sample site.
3. Press "ENTER" after you have input the desired landmark name.
4. Press "ENTER" to accept the current latitude.
5. Press "ENTER" to accept the current longitude.

If sample site is predetermined from navigational charts use the following procedure to enter landmarks.

6. Press, "MARK" and name.
7. Use arrow keys to change latitude and longitude
8. Press "ENTER" to accept each.

If sample site is determined in the field use the following procedure to enter landmarks.

9. Press, "MARK" and name each sample site with a unique ID.
10. Press "ENTER" to accept the current latitude.
11. Press "ENTER" to accept the current longitude.

To go to a waypoint,

12. Press "GO TO",

13. Use the left/right arrows until desired destination (i.e. named sample sites) is displayed.
14. Press, "ENTER".
15. A compass is displayed with an arrow indicating the bearing to the next station. Directional arrow should not be used in place of navigational charts when motoring between sample sites.

Calibration: Calibration for the unit should only be done if it is moved more than 300 miles from original position. The process will adjust the elevation, initial earth position, date, and time.

1. Turn GPS unit on by pressing "PWR".
2. Use the arrow key to select from the flashing text the appropriate region (for example: USA).
3. Press, "ENTER".
4. Use the arrow key to change the flashing text to the country or state of present location (for example: Puerto Rico, VI is not an option).
5. Press, "ENTER".
6. Enter the approximate elevation for position using the arrow key. Leave this at 0 if it is unknown.
7. Press, "ENTER".
8. Use the arrow key to enter the time, then press, "ENTER".
9. Use the arrow key to enter the date, then press, "ENTER".

The GPS unit will then begin to search for satellites and pinpoint the latitude and longitude. This may take several minutes.

Maintenance: Battery replacement. Unit should be rinsed in freshwater if exposed to salt water.

AMS Hydrocarbon Test Kit

Specifications: Positive result indicates concentration of 3ppm or more, but not actual concentration. This kit is for "yes" or "no" hydrocarbon contents tests only. It is not an analytical test.

General Description and Conditions for Use: Kit contains ten disposable sample vials filled with a pre-measured amount of Leak Tracer Dye for measuring hydrocarbons.

Standard Operating Procedure:

1. Fill test tube ½ full with water sample.
2. Turn test tube to 45-degree angle and look at the center of top of the water.
3. Complete coloration change of top of water indicates phase-separated product.
4. Shake mixture thoroughly to obtain mix.
5. <u>Let mixture settle completely</u>.
6. All of water showing coloration change indicates dissolved phase product.

The water sample is added to the tube and shaken. A colored line at the top of the water indicates a positive result of 3ppm or more hydrocarbons. Establish baseline at limited number of sampling stations closest to potential source of hydrocarbon contamination (i.e. at watershed or storm drain discharge). Instructions included in the kit will explain how much sample is needed and other procedures.

Calibration: None

Maintenance: Kit needs to be kept dry.

Piccolo Plus pH Meter

Specifications: Meter measures pH and temperature (from 0 to 70°C). The electrode on the meter is 6 1/2" long. Piccolo Plus has meter, pH electrode, 1.5V batteries, pH 4 and pH7 buffer solutions, and a small screwdriver for calibrations. The meter is stored in a hard plastic carrying case (dimensions 7.8”x 6”x 2.3”). The Piccolo Plus weighs 3.5 ounces.

General Description and Conditions for Use: The Piccolo Plus meter is a small, light, battery operated device that is easy to use in the field. It will determine the pH and temperature of a given solution. The meter must be kept dry. Only the pH electrode should come in contact with any solutions or fluids, and it should be stored wet (distilled water or other neutral solution) with cap on.

Standard Operating Procedure:
The electrode should be rinsed with distilled water before and after use.

1. Connect the electrode to the meter (both the printings on the body and on the electrode facing upwards). Turn the meter on by the OFF/pH/°C switch and select the pH position.
2. Dip the electrode into the solution. Do not immerse the electrode in the solution above the maximum level printed on the rear.
3. Stir gently until the display shows a stable reading. The instrument automatically compensates for the temperature variation.
4. Before dipping into a new sample, rinse the electrode with the new sample solution. This will insure and accurate measurement.
5. When finished rinse electrode with distilled water and replace cap leaving electrode wet.

It is important to note that the electrode pulls apart from the meter very easily, so care should be taken when pulling the cap off the electrode to not pull the meter off.

Calibration: For single point calibration:
Dip the electrode into a buffer solution close to the operation range and adjust the value by the OFFSET calibration trimmer (white screw on right side front of meter). A screwdriver is provided with the meter.

For dual point calibration:
Dip the electrode into pH 7.01 @ 25°C buffer solution and adjust the reading by the OFFSET calibration trimmer (white screw on RIGHT side front of meter) to the pH value corresponding to the buffer solution temperature. Then dip the electrode into the pH 4.01 @ 25°C buffer solution and adjust the reading by the SLOPE calibration trimmer (white screw on LEFT side front of meter) to the pH value corresponding to the buffer solution temperature.

Maintenance: The probe should be rinsed with distilled water before and after each use. Cover the probe with the cap provided, leaving probe wet, between uses. Batteries will need to be replaced depending on how often the meter is used. The electrode will also have to be replaced occasionally. If the electrode remains dry for a long period, before taking any measurements or calibration, it is necessary to reactivate it by dipping it in to a neutral solution for about 4 hours.

YSI Multi-parameter Water Quality Meter

Specifications: The YSI multi-parameter Water Quality Meter is a hand held meter in a watertight casing with backlit LCD. Parameters include salinity, dissolved oxygen, conductivity, and temperature. Salinity range is between 0 to 80 parts per thousand (ppt), resolution is 0.1 ppt, and accuracy is ± 0.1ppt. Dissolved oxygen (DO) in the solution is measured between a range of 0 to 20 mg/L, resolution is 0.001 mg/L, and accuracy is ± 0.3 mg/L. The conductivity range is 0 to 499.99µS, resolution is 0.1µS, and accuracy is ±0.5% full scale. Finally, the temperature range is 0° to 45°C, resolution is 0.1°C, and accuracy is ±0.1°C. The weighted probe is a non-detachable combination of a four-electrode cell for conductivity measurement and a polarographic Clark-type sensor for dissolved oxygen detection. Cable connection between meter and probe is 50 feet long. Internal memory stores up to 50 data sets. Model includes six membrane caps, one bottle of O_2 probe solution, one sanding disk, hand strap, and six 1.5 V AA batteries

General Description and Conditions for Use: This hand-held meter is designed for environmental applications. It will measure salinity, conductivity, dissolved oxygen, and temperature with one single probe. The meter will simultaneously display temperature with each selected parameter. The probe should be kept in the calibration storage chamber (located on the side of the meter) when not in use to prevent contamination or breakage. Use of the YSI meter requires advanced planning because the calibration process requires thirty minutes. Each time the meter is turned off it must be recalibrated before additional measurements can be taken. Therefore it is recommended that once the unit is calibrated it be left on until all sample sites are completed unless time between samples is greater than 1.5 hours.

Standard Operating Procedure: The meter must be calibrated before each use if it has been turned off. The sponge within the calibration/storage chamber must always be wet with distilled water. Calibration should take place at a temperature as close as possible to the sample temperature.

1. Wet sponge inside the calibration chamber if it is not already wet and insert probe.
2. Turn meter on by pressing "ON/OFF" button.
3. Press "MODE" button until the dissolved oxygen is displayed in mg/L or %.
4. Wait for the dissolved oxygen and temperature readings to stabilize.
   NOTE: **The calibration procedure takes thirty minutes.**
5. Use two fingers to press and release the up arrow and the down arrow buttons at the same time.
6. The LCD will prompt you to enter the local altitude in hundreds of feet. Use the arrow keys to increase or decrease the altitude. For example, when calibrating instrument on a dock or from a boat "0" should be entered.
7. Press, "ENTER" when proper altitude is displayed.
8. The meter should now display CAL in the lower left of the display, the calibration value should be displayed in the lower right of the display, and the current % reading (before calibration) should be on the main display. Make sure the current % reading (large display) is stable.
9. Press, "ENTER". The display should read SAVE then return to normal operating mode.

Once the meter has been calibrated, DO NOT TURN IT OFF until completely done with desired samples. Now that calibration is complete the meter is ready to take and record measurements.

1. Lower probe into sample or ocean for testing
2. Press the "MODE" button to display desired parameter.
3. Record reading in notebook along with ID codes used in the GPS unit. Repeat for each parameter (dissolved oxygen, temperature, conductivity, salinity).
4. Data for 50 stations can be saved for recording at a later time but care must be taken to associate sample ID # with ID codes in GPS units. To save data press "Enter" button and hold for approximately 2 seconds while any parameter is displayed. The meter will flash SAVE on the display along with station identification number (consecutive numbers from 1 to 50).

When data for 50 stations have been saved, the display will flash FULL on the screen. This message will remain on the screen (even after power down) until a button is pressed.

To recall stored data.

1. Press "MODE" until "rcl" (recall) is displayed on the screen along with the station ID number in the lower right corner.
2. Press up or down arrow button to scroll through the saved data sets. When the correct station ID# is displayed, press, "ENTER" to display the data.
3. The meter will display dissolved oxygen in % saturation and temperature.
4. Press "ENTER" and the meter will display dissolved oxygen in mg/L and the temperature.
5. Press, "ENTER" again and again to review the conductivity, specific conductivity (temperature compensated), and salinity readings. All will be displayed with temperature.
6. Transcribe data to a notebook.

7. Press up or down arrow button to scroll to the next saved data set.

To erase stored data.

1. Press "MODE" until "ErAS" (erase) is displayed on the screen.
2. Depress and hold down ARROW and "ENTER" buttons simultaneously for about 5 seconds.
3. All stored data has been erased when "DONE" flashes on the display for 2 seconds. The meter will return to normal operation after completion. NOTE: Data in all 50 stations will be erased completely and lost forever. Do not use the erase function until all saved data has been transcribed.

Calibration: Built-in calibration/ storage chamber makes field calibration easy. Moisten enclosed sponge with distilled water to provide a 100% water-saturated air environment for calibration. One calibration adjusts instrument for both mg/L and % air saturation measurements. Instructions for calibration are included in Standard Operating Procedures above. Meters are factory- calibrated for conductivity.

Maintenance: Rinse probe in freshwater and return to storage chamber. Wipe meter with a damp cloth to remove salt spray, wipe dry and return to carrying case. Meter requires occasional battery and membrane replacement.

Note: Carrying case is recommended for safe transportation of instrument on boats. Replacement batteries are $5.00 for a pack of four (Cat. #P-09376-01). Replacement membrane kit, which includes six standard membrane caps, one bottle of O_2 solution, and one sanding disk, is $40.00 (Cat. # P-05519-16). Cable also comes in other lengths (10, 25, and 100 feet).

Van Dorn Bottle

Specifications: One-liter clear plastic water sample bottle with 20 meters of calibrated nylon line. Brass messenger triggers the release mechanism and seals the sampler chamber at the desired depth. Water outlet is located on side of bottle.

General Description and Conditions for Use: Although the bottle has a lead collar, which assures rapid descent and minimal drift, operator should ensure that boat drift is minimized. Care should be taken that bottle does not impact bottom or become entangled in the coral reef or boat propeller. If algae or other debris has prevented stopper from closing properly, retake sample. A one meter weighted line can be attached to the center of the bottle to ensure that a sample is taken exactly one meter above the bottom every time.

Standard Operating Procedure:

1. To set trigger mechanisms hold the Van Dorn Bottle by the brass handle with triggers in the "up" position. Pull the cable attached to one plunger outward and hook the loop over the trigger. This will remove plunger from sampling chamber.
2. After the loop is hooked over the trigger, attach the other loop to the trigger. This will remove the other plunger from the sampling chamber.
3. Lower water Van Dorn Bottle to designated depth by the calibrated line while holding the brass messenger in one hand.
4. Hold the line in a vertical position over the sampler and release brass messenger to trigger closing mechanisms on Van Dorn Bottle. After the messenger trips the closing mechanism, the sample within the collection chamber is sealed from mixing with un-sampled water.
5. Gradually pull the Van Dorn Bottle to the surface with the line and carefully rest sampler on level surface.
6. Aliquots or portions of the sample are taken by standing the Van Dorn Bottle upright on one plunger and unclamping the outlet tubing. Partially remove the other plunger to prevent formation of a vacuum. Use a little water from Van Dorn Bottle to rinse a clean 1 l jar then fill the jar with

the water sample. Ensure that each sample jar is properly labeled with a unique code that cannot be removed or rubbed off.

Calibration: None.

Maintenance: Rinse Van Dorn Bottle in fresh water and air dry before storage. Do not store with trigger engaged.

LITERATURE CITED

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APPENDIX 1:

PERMANENT WATER QUALITY MONITORING STATIONS

USED IN THE

AMBIENT WATER QUALITY MONITORING PROGRAM

OF THE

DEPARTMENT OF PLANNING AND NATURAL RESOURCES

APPENDIX 1

PERMANENT WATER QUALITY MONITORING STATIONS

The lists given below comprise the water quality monitoring stations used by the Department of Planning and Natural Resources, Division of Environmental Protection (DPNR-DEP) for its ongoing water quality monitoring program.

Table A-1: St. Croix-Basic Water Quality Monitoring Stations

Station Number	Location	Class

Station Number	Location	Class
STC-1	Lagoon Recreation Beach	B
STC-2	Ft. Louise Augusta Beach	B
STC-3	Buccaneer Hotel	B
STC-4	Tamarind Reef Lagoon	B
STC-5	Green Cay Beach	B
STC-6	Buck Island Beach	A
STC-7	Buck Island Anchorage	A
STC-8	Reef Club Beach	B
STC-9	St. Croix Yacht Club Beach	B
STC-10	Cramer's Park	B
STC-11b	Issac Forereef	B
STC-12	Grapetree Beach/Turner Hole	B
STC-13a	Great Pond	B
STC-13b	Robin Backreef	B
STC-14a	Halfpenny Bay-Manchenil	B
STC-14b	Halfpenny Backreef	B
STC-15	Canegarden Bay	B
STC-16	Northwest End, Hess E Channel	C
STC-17	Northwest End, Hess W Channel	C
STC-18	Limetree Bay	C
STC-19	Krause Lagoon Channel	C
STC-20	Martin Marietta	C
STC-21	Spoils Island Channel	B
STC-22a	Treatment Plant Outfall	B
STC-22b	Outfall Break	B
STC-23	Public Dump	B

Table A-1: Continued

Station Number	Location	Class
STC-24a	Texaco Buoys	B
STC-24b	Rum Plant Outfall	B
STC-25	Carlton Beach	B
STC-26	Good Hope Beach	B
STC-27	Sandy Point Public Beach Resort	B

Station Number	Location	Class
STC-28	Frederiksted Public Dock	C
STC-29	Magic Isle Beach Resort	B
STC-30	Sprat Hall Beach	B
STC-31	Davis Bay	B
STC-32	Cane Bay	B
STC-33a-j	Salt River Estuary Stations	B
STC-34	St. Croix by the Sea	B
STC-35	Long Reef, Forereef W	B
STC-36	Long Reef, Forereef E	B
STC-37	Christiansted Harbor Entrance W	B
STC-38	Christiansted Harbor Entrance E	B
STC-39	Altona Lagoon Inlet	C
STC-40	St. Croix Marine Marina	C
STC-41	Gallows Bay	C
STC-42	Public Wharf	C
STC-43	Water Gut	C
STC-44	Prostestant Cay Beach	C
STC-45	Christiansted Harbour	C
STC-46	V. I. Water and Power	C
STC-47	Mill Harbour Condominiums	B
STC-48	Long Reef Backreef W	B
STC-49	Long Reef Backreef E	B
STC-50	Long Reef, Old Outfall	B
STC-51	King Cross Street, Storm Drain	C

Table A-2: St. Croix-Beach Monitoring Stations

Station Number	Location

Station Number	Location
STC-B1	Yacht Club Beach
STC-B2	Cramer’s Park Beach
STC-B3	Divi St. Croix Beach
STC-B4	Frederiksted Pool Beach
STC-B5	Frederiksted Public Beach
STC-B6	Rainbow Beach Club
STC-B7	Butler Bay Beach
STC-B8	Carambola Beach
STC-B9	Cane Bay Beach
STC-B10	Gentle Winds Beach
STC-B11	Columbus Landing Beach
STC-B12	Pelican Cove Beach
STC-B13	Mill Harbor Beach
STC-B14	Hotel on the Cay Beach
STC-B15	Altona Lagoon Beach
STC-B16	Fort Louise Augusta Beach
STC-B17	Buccaneer Beach
STC-B18	Shoys Beach
STC-B19	Chenay Bay Beach
STC-B20	Candle Reef Beach
STC-B21	Coakley Beach
STC-B22	Reef Beach
STC-B23	Club STX
STC-B24	Gallows Bay Fisherman’s Pier
STC-B25	C’sted Wharf
STC-B26	Boy Scout Camp
STC-B27	Tamarind Beach Hotel
STC-B28	Salt River Marina
STC-B29	Water Gut
STC-B30	Green Cay Marina
STC-B31a	Billy French, S
STC-B31b	Billy French, N

Table A-3: St. Croix-Salt River Intensive Study Monitoring Stations

Station Number	Location
STC-33A	Columbus Landing
STC-33B	Shallow Grass Bed
STC-33C	Salt River Marina
STC-33D	Sugar Bay
STC-33E	Deep Grass Bed
STC-33F	Beach
STC-33G	NOAA Dock
STC-33H	Bird Sanctuary
STC-33I	Steeple
STC-33J	Cove

Table A-4: St. John-Basic Water Quality Monitoring Stations

Station Number	Location	Class
STJ-43a	Cruz Bay, north of Pier	B
STJ-43b	Cruz Bay, south of Pier	B
STJ-43c	Cruz Bay Creek, north of seaplane ramp	B
STJ-43d	Cruz Bay Creek North	B
STJ-44a	Trunk Bay	A
STJ-44b	Hawksnest Bay	B
STJ-44c	Cinnamon Bay	B
STJ-44d	Francis Bay	B
STJ-45	Great Cruz Bay	B
STJ-46	Chocolate Bay	B
STJ-47	Rendezvous Bay	B
STJ-48	Fish Bay	B
STJ-49	Genti Bay	B
STJ-50	Little Lameshur Bay	B
STJ-51	Great Lameshur Bay	B
STJ-52	Salt Pond Bay	B
STJ-53	Coral Bay	B
STJ-54	Caneel Bay	B
STJ-55	Turner Bay	B

Table A-5: St. Thomas-Marine Water Quality Monitoring Stations

Station Number	Location	Class
1	Crown Bay, near outfall	C
2	Crown Bay, near Tamarind outlet	C
3	Sub-base	C
4	Krum Bay	B
5A	Lindberg Bay, east	B
5B	Lindberg Bay	B
6A	Dump – Station Eliminated	B
6B	Airport/College Cove	B
6C	SW Road, near Red Point outfall	B
6D	Flat Cay, north east corner	B
7A	Brewers Bay	B
7B	Perserverance Bay	B
8	Fortuna Bay	B
9	Botany Bay	B
10	Stumpy Bay	B
11	Santa Maria Bay	B
12	Caret Bay	B
13	Dorothea	B
14	Hull Bay	B
15A	Magens Bay, north east	B
15B	Magens Bay, north west	B
16A	Mandahl Bay	B
16B	Mandahl Bay Marina	B
17A	Spring Bay	B
17B	Sunsi Bay	B
18	Coki Bay	B
19	Water Bay	B
20	Smith Bay	B
21A	St. John Bay	B
21B	Red Bay	B
22A	Red Hook Bay	B
22B	Vessup Bay	B
23	Great Bay	B

Station Number	Location	Class
24	Cowpet Bay	B
25	Nazareth Bay	B
26	Benner Bay	B
27A	Mangrove Lagoon, near treatment plant	B
27B	Mangrove Lagoon, off sanitary landfill	B
28A	Bovoni Bay	B
28B	Bolongo Bay	B
29A	Frenchman's Bay	B
29B	Limetree	B
30	Morning Star Bay	B
31A	Flamboyant Cove	B
31B	Hassel Island, off Navy Dock	B
31C	Hassel Island, Careening Cove	B
32A	Long Bay, near South Dolphin	C
32B	Long Bay, northeast corner	C
33	Long Bay, off outfall	C
34	Long Bay, off pump station	C
35	Gordon Cay	C
36	St. Thomas Harbor, north of coast guard pier	C
37	St. Thomas Harbor, Cay Bay	C
38	Haulover Cut	C
39	Water Isle, East Gregerie Channel	B
40	Water Isle, hotel beach	B
41	Water Isle, Flamingo Bay	B
42	Water Isle, Sprat Bay	B

APPENDIX 2:

DATA RECORDING FORM

(EXCEL TEMPLATE)

A1 = PAGE 1

	A	B	C	D	E	F	G	H
1	PAGE 1							
2	Sampling Location:							
3	Lat & Long							
4	Closest construction site:							
5	Closest VI DPNR water quality station:							
6	Date:							
7	Time (24 hour clock):							
8	After or before low or high tide:							
9	Observers Name:							
10			Transect #1					
11			Station #1		Station #2		Station #3	
12			(1 m depth)		(5 m from Station #1)		(15 m from Station #1)	
13			surface	bottom	surface	bottom	surface	bottom
14	Secchi	reading #1						
15	Disk	reading #2						
16	(meters)	reading #3						
17	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
18	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
19	Nephelometer	reading #1						
20	(ntu)	reading #2						
21		reading #3						
22	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
23	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
24	Light Meter	reading #1						
25	(% transmissivity)	reading #2						
26		reading #3						
27	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
28	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
29	Temperature	reading #1						
30	(Fahrenheit)	reading #2						
31		reading #3						
32	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
33	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
34	Salinity	reading #1						
35	(ppt)	reading #2						
36		reading #3						
37	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
38	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
39	Dissolved	reading #1						
40	Oxygen	reading #2						
41	(mg/l)	reading #3						
42	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
43	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

APPENDIX 2:

DATA RECORDING FORM

(EXCEL TEMPLATE)

A1 = PAGE 1

	A	B	C	D	E	F	G	H
1	PAGE 1							
2	Sampling Location:							
3	Lat & Long							
4	Closest construction site:							
5	Closest VI DPNR water quality station:							
6	Date:							
7	Time (24 hour clock):							
8	After or before low or high tide:							
9	Observers Name:							
10			Transect #1					
11			Station # 1		Station # 2		Station #3	
12			(1 m depth)		(5 m from Station #1)		(15 m from Station #1)	
13			surface	bottom	surface	bottom	surface	bottom
14	Secchi	reading #1						
15	Disk	reading #2						
16	(meters)	reading #3						
17	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
18	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
19	Nephelometer	reading #1						
20	(ntu)	reading #2						
21		reading #3						
22	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
23	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
24	Light Meter	reading #1						
25	(% transmissivity)	reading #2						
26		reading #3						
27	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
28	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
29	Temperature	reading #1						
30	(Fahrenheit)	reading #2						
31		reading #3						
32	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
33	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
34	Salinity	reading #1						
35	(ppt)	reading #2						
36		reading #3						
37	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
38	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
39	Dissolved	reading #1						
40	Oxygen	reading #2						
41	(mg/l)	reading #3						
42	Average		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!
43	Standard deviation		#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!	#DIV/0!

APPENDIX 3:

MODEL SAMPLING TRIP

MODEL SAMPLING TRIP

Persons engaged in field activities on a consistent basis should develop a habit of pre-trip planning. This essentially consists of making a checklist of activities to be carried out usually a day of two prior to the actual field trip. This would include:

- Submitting requisitions[1] for vehicle;
- Submitting requisitions for purchase of materials, if necessary;
- Cleaning equipment;
- Ensuring that any required reagents or other materials are available;
- Packing the equipment into suitable containers for transportation during the field trip

A typical sampling trip would consist of the following steps:

Step 1: Equipment Check -- Prior to sampling marine waters to determine possible water quality violations as a result of construction activities, all equipment must be checked to ensure it is calibrated and in good working order. All necessary materials should be taken, including data sheets, writing utensils (i.e., lead pencil is preferable over ink pens), maps/nautical charts, and a camera. Photographs are usually a good way to document possible water quality violations and/or inappropriate construction activities.

Step 2: Documentation Review -- Sampling protocols should be reviewed and kept handy during the sampling trip, to ensure proper collection of data. In addition, it is important to review a construction site's stormwater, erosion, and sediment control plan to make sure the plan is being followed and appropriate BMPs are put in place.

Step 3: Sampling Transects -- After observing the site and adjacent waters, transects should be drawn on a nautical chart following the sampling scheme discussed in Chapter 3. If a plume in the water is present or runoff from the site can be observed, then it is important to make sure the transects run through the plume and it is adequately sampled.

Step 4: Recording of Data -- All measurements should be recorded immediately and repeated (three samples collected at the surface and three samples collected at the bottom per station) to ensure validity. Visual descriptions should also be recorded while on-site to obtain the most accurate description of possible observations such as stormwater runoff, turbidity plume(s), odors, unusual color, oily sheen, fish kill or any other unusual mortality of marine organisms, algal bloom, or floatable debris.

Step 5: Violation Response -- If measurements confirm a water quality violation or firsthand observations indicate a problem, appropriate actions must follow, whether it is a

[1] The timing for submission of requisitions for vehicles, purchases, etc. is usually dictated by departmental policies and procedures.

cessation in construction operations, or an adjustment in the best Management Practices used. See manual for detail of appropriate responses to particular observations.

Step 6: Equipment Maintenance -- After water quality sampling equipment is used, it should be cleaned and calibrated if necessary. See Chapter 6ix for details on calibration and maintenance of equipment.